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The present investigation was addressed to the question of whether or not the illusion of simultaneous brightness contrast is susceptible to a practice effect as are the Poggendorff, Zoellner, and Mueller-Lyer illusions. A nativistic, or peripheral, explanation of brightness contrast would predict no change in the degree of the illusion as a consequence of practice. An empiricistic, or central, explanation would predict a decrement in the degree of the contrast effect following successive practice trials.

Five Ss, 3 male and 2 female students of advanced status in the University, participated. Using the method of adjustment, each S attempted to equate the brightness of an adjustable field with that of a standard field of 1 ft.-L. luminance. On each of 10 consecutive days, S rendered: (1) 10 control comparisons in the absence of any contrast effect, and (2) 50 experimental judgments, during which the standard field was surrounded by an inducing field of 4 ft.-L. luminance.

Statistical analysis showed, at a borderline level of significance, a difference among practice days for the experimental condition. The data show an apparent increase in the

effect of the illusion, especially during the first few days of the experiment. Unexpectedly, too, a significant difference among practice days was found for the control condition.

Possible explanations for these anomalous results were discussed. Although the independent variable of practice apparently had an effect opposite to that predicted, it was suggested that the instability of performance across practice days renders a totally nativistic explanation of brightness contrast questionable. It was concluded that at the very least the present data indicate that simultaneous brightness contrast is subject to many subtle influences.

SIMULTANEOUS BRIGHTNESS CONTRAST AS A FUNCTION OF PRACTICE

by

Gary McClure

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Approved by

Director

APPROVAL SHEET

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INTRODUCTION

Simultaneous brightness contrast has long been a matter of interest to the scientist investigating the visual processes, and particularly to the psychologist concerned with perception. Efforts to ascertain the determinants of this illusion have assumed many forms, but such research can usually be identified as having been generated within the framework of either empiricism or nativism. The major tenets of these diverse views of perception are generally known and will not be repeated here. They are well summarized, however, by the following statements from Helmholtz and Hering, the traditional spokesmen for the two schools of thought, respectively.

First, Helmholtz:

> ....The fundamental thesis of the empirical theory is .... [that] ....The sensations of the senses are tokens for our consciousness, it being left to our intelligence to learn how to comprehend their meaning (Helmholtz, 1866, Vol. III, p. 533; italics in original).

Thus it is very clear that for Helmholtz perception is a central, cognitive process. Furthermore, illusions are the results of "errors of judgment" which in turn are a consequence of prior experience and learning (Hurvich and Jameson, 1966, p. 88).

In sharp contrast with this position is Hering's contention that:

> ....one must not represent as products of experience the same innate functions of the visual system on the basis on which these experiences were originally acquired (Hering, 1920, p. 21; italics in original).

Equally interesting is Hering's statement that:

> ....it would be rash to regard the cortex alone as the locus of "psychophysical" processes and to exclude everything else, especially the retina (Hering, 1920, p. 23).

Hering, therefore, placed much emphasis on innate, physiological mechanisms, the locus of which was peripheral rather than central, to account for perceptual processes.

One may legitimately ask which theoretical position is more consonant with the empirical data. This is a difficult question to answer, inasmuch as advocates of both

schools have often interpreted the same data as supporting their particular views. The "critical experiment" remains yet to be conducted; and there now seems to be occurring, in fact, a resurgence of the empiricism-nativism controversy (Parrish, 1966; Parrish and Smith, 1967).

Hurvich and Jameson (1964) account for the latter resurgence in terms of recent technological developments in the area of visual electrophysiology. Implicit in their comments is their assumption that contemporary research has demonstrated the validity of certain physiological interactions anticipated by Hering over half a century ago. It is true that Hering's concept of "reciprocal interaction" has received rather impressive support from Hartline's (1949) research with Limulus. Although the horizontal interconnections in the human retina may turn out to be homologus to those mediating lateral inhibition in Limulus, Graham (1965) points out, however, that generalization of Hartline's findings to the human visual system should be done only with great caution. The need for caution is especially apparent if we consider that certain manipulations which produce very miminal changes in retinal stimulation can materially alter S's perception of simultaneous brightness contrast. Such

findings are interpreted as providing support for a cognitive, or central, position in the tradition of Helmholtz's empiricism.

Specifically, Berman and Leibowitz (1965) have measured simultaneous brightness contrast as a function of the orientation of a test object, shaped as a figure "8", on a half-light and half-dark background divided vertically. The type and width of a contour separating the figure-halves on the divided background was also investigated. Subjective contrast was significantly greater when the figure "8" was presented with its rings on backgrounds of different brightness than when each ring lay on both backgrounds. Additionally, greater contrast was evident when the figure "8" was presented in a horizontal position rather than a vertical position. Regarding contour, the results indicate that when the figure-halves were moved apart, each to its own surround, contrast was greater than when a dividing line separated the halves. When, however, contour was varied, using dividers ranging in width from .005 to .64 in., perceived simultaneous contrast increased as the width of the dividers increased. These results led the authors to conclude that:

> ....simultaneous contrast is not a simple function of luminance and spatial variables.

> This does not imply that these variables are not fundamental to contrast, but rather that additional concepts are needed to fully explain subjective contrast with more complex stimulus configurations (Berman and Leibowitz, 1965, p. 256).

Even more impressive, Parrish (1966) has found that the variable of instructional set significantly influences the degree of simultaneous brightness contrast. In Parrish's study, all Ss were treated the same way except for a critical instructional variable. One group received instructions designed to instill a "whole-perceiving" attitude, and another group an "analytical" attitude. The results showed that Ss receiving analytical instructions prior to the experimental task evidenced the simultaneous brightness contrast effect significantly less than those who received the whole-perceiving instructions. These data indicate that it is possible to alter the magnitude of this illusion without changing the stimulus situation to which the Ss are exposed. The conclusion would seem to be that central processes play a significant role in the perceptual phenomenon of simultaneous brightness contrast.

If simultaneous brightness contrast is, indeed, an effect which depends upon learning and experience, one might expect it to change in degree with learning and experience. As is well known, such concomitant changes have been established with some other illusions. Thus, in his classical study of 1902, Judd demonstrated that the effect of the Mueller-Lyer illusion diminished with a long series of practice trials. In Judd's study, S was not provided with any knowledge of results during the practice trials. He was simply exposed repeatedly to the stimulus situation and instructed to equate subjectively the main lines of the Mueller-Lyer figure. Performance, therefore, improved simply as a consequence of continued practice with the experimental task. Lewis (1908) and Seashore, et al. (1908) conducted similar investigations and obtained the same results. Furthermore, Woodworth and Schlosberg (1954, p. 422) report that the Poggendorff and Zoellner illusions diminish with practice trials as does the Mueller-Lyer. Historically, these data have been interpreted as supporting a learning, that is, empiricistic, explanation of the perceptual processes involved in these illusions (Dewar, 1967).

Koehler and Fishback (1950) took issue with such expla-

nations and renewed a controversy that had lain dormant nearly half a century. They offered an alternative explanation based on brainfield, satiation theory (Koehler and Wallach, 1944). Although it is true that Hering's theory placed its emphasis on the visual mechanisms at the retinal level, as opposed to the cortical emphasis implicit in Koehler and Wallach's satiation theory, the important point is that the advocates of an essentially nativistic position gained a formidable ally. Their position, however, was challenged later by Mountjoy (1958) and Day (1962), and the ensuing developments have been traced rather fully by Dewar (1967).

Dewar himself has conducted an extensive investigation of certain stimulus characteristics of the Mueller-Lyer figure, as they relate to the practice decrement in the illusion. Basing his statement on the results of five experiments, Dewar (1967, p. 504) concludes that:

> The decrement in the magnitude of the illusion after 100 trials was found to be inversely related to the angle between the oblique lines and the prominence of the horizontal lines relative to that of the obliques, but unrelated to the length of the oblique lines.

> The practice decrement was attributed to an increase in attention to the horizontal line of the figure.

Dewar interprets his results in terms of Gibson's (1959) theory of perceptual learning, which emphasizes the role of experience in the elaboration of the stimulus situation.

The parametric investigations by Dewar are of interest. For present purposes, however, the salient point to be drawn from these studies is that, whatever the degree and for whatever the reason, a decrement does in fact occur as a consequence of practice trials. In other words, Dewar's more current data are in complete accord with Judd's original conclusions. This decrement is exactly what Helmholtz himself would have predicted, for in his own words we have the following statement:

> An eye that is trained in estimating size, distance, etc., will be on its guard against many illusions into which an untrained eye will be betrayed, and it is the same way with determinations of color; and hence the author's belief that practiced eyes see contrast less vividly than unpracticed eyes (Helmholtz, 1866,

Vol. 11, p. 295).

It seems logical, especially in the light of the foregoing quotation from Helmholtz, to raise the question of whether or not the practice effect would manifest itself with respect to the particular illusion of simultaneous brightness contrast, inasmuch as the latter is a prime focus of the conflicting points of view between Hering and Helmholtz. To the writer's knowledge, however, brightness contrast as a function of practice has not been investigated. The implications of such a study would be straightforward: if this illusion, which has lately been explained in terms of physiological factors, can be shown to dissipate as a function of practice trials, then a totally nativistic position would be brought into serious question.

The purpose of the present experiment followed from the foregoing logic. That purpose was to investigate the effect of practice upon the degree of simultaneous brightness contrast.

PROCEDURE

Apparatus

The primary item of apparatus was the "Brightness Comparator" (Model D-0659) built by the Polymetric Company of Reading, Pennsylvannia. Briefly, the essential features of the instrument are four independently controlled fields of illumination arranged in such a way that, on each of two separate panels, there is a circular, disc-shaped field which is itself surrounded by a circular, ring-shaped field, or annulus. The resulting concentric circles have an overall diameter of 7 7/8 in., the inner disc alone being 4 1/8 in. in diameter. The two fields on each panel are connected to the control unit by an 8-ft. cable. The luminance of each of the four fields is adjustable from 0 to 5 ft.-L., simply by turning one of four knobs on the front of the control unit. The instrument is functionally very similar to one employed by Heinemann (1955).

The apparatus was situated in a large, totally darkened classroom of conventional construction. Extraneous sounds were masked by the continuous, broadspectral noise

generated by the operation of two large air conditioners in the experimental room.

The two stimulus panels were placed adjacent to one another, 8 1/2 in. on center, on a table 36 in. in height. That table was situated 72 in. directly in front of another table, 28 in. in height, at which S was seated. The control unit was placed at the extreme right of S as he faced the two luminous panels. A rest for S's right arm was attached directly in front of the control knob which S adjusted, with his right hand, during the experimental task. A stationary hand rest for S's left hand was mounted on the extreme left of the table surface. The hand rest, in conjunction with the fixed position of the control knob, considerably restricted variations in posture. Hence, in his seated position, S viewed the stimulus situation at eye level and at an essentially fixed distance from the stimulus panels.

In an effort to control for any stray light from E's reading lamp on the control unit, black velvet was draped around the latter, thereby removing from S's peripheral visual field any distractions from either the control unit itself or from E's actions during the recording of scores. Additionally, black velvet was suspended horizontally between the top

edge of the table supporting the stimulus panels and the top of the table at which S was seated. Reflection resulting from the light emitted by the stimulus panels themselves was thus rendered negligible. Tactual cues on the control knob were eliminated by covering it with a wide, continuous rubber band.

Subjects

Five psychology students, 3 male and 2 female, participated in the present experiment. Four of the Ss were graduate students; the fifth was an honors senior. Their mean age was 24 years.

Method

After the selection of an S, a mutually acceptable testing time was decided upon and held constant during S's 10 day period of service.

Upon his first arrival at the testing room, S was allowed a 12-min. dark-adaptation period. During this time the essentials of apparatus and procedure, such as the adjustment knob, arm rest, and comfortable seating were discussed. As the end of the dark-adaptation period approached, S was instructed to take his seat. E then read the following instructions:

I am interested in the ability of

people to make perceptual matches between brightness fields of different luminances. Your task will be to vary the brightness of the disc you see on your right [E raised the luminance of the center disc on the right panel to a value of 1 ft.-L.] until it appears to you to be exactly the same as the disc on your left [E raised the luminance on the center disc on the left panel to a value of 1 ft.-L.] using the adjustment knob shown to you a moment ago. In order to make the best match possible, look back and forth freely between one disc and the other as you simultaneously vary the adjustment knob, until you are confident that you have obtained the best match you are capable of rendering. When you have done so, remove your hand from the control knob and allow it to rest in the arm rest. At that point, I will record the results, reset the controls, and signal you to begin the next matching trial. Are there any questions?

Thus, S began his first day's service by making 10 comparisons between the standard and test field in the absence of the contrast effect resulting from the presentation of the background annulus around the disc on the standard stimulus panel. After introducing the standard and test field disc at a luminance value of 1 ft.-L. each, as described, E then randomly varied the initial luminance of the test field on each trial, up or down; the direction of the variations was predetermined from a table of random numbers. The luminance of the standard disc remained always at 1 ft.-L.. S adjusted the test field luminance until it was subjectively equal to that of the standard. After each match, E recorded the setting upon which S settled.

At the end of the 10 control comparisons, S was asked to listen to the following instructions:

> On the next series of trials your task will be exactly the same. However, there is now a bright circular background around the disc on your left [E raised the annulus to a value of 4 ft.-L.] . This combination of visual stimuli produces a strong illusion, as you know. It is, therefore, very important

that you make every attempt possible to make your matches accurately and objectively without paying any attention to the brighter circle around the disc on your left. In other words, be sure that you match the disc on your right with the disc on your left independently [E read with emphasis] of the bright circle around the left disc. Are there any questions?

The experimental condition, therefore, involved the presence of the inducing annulus around the center disc on the standard stimulus panel. S's task remained unchanged, however, and E followed the same procedure uninterrupted for an additional 50 trials. As in the control trials, the initial setting of S's knob was varied randomly, to produce equal numbers of ascending and descending trials; S was always free, however, to search in either direction for a satisfactory setting. The standard disc was always on S's left, the adjustable disc always on his right.

To insure that S fully understood the nature of his task, he was asked the following question at the conclusion of the first experimental session:

> In other words, you are saying that if I removed the background circle from around the center disc on the panel on your left, then the remaining two disc would represent the best phenomenological match you are capable of rendering? [All S's replied in the affirmative.]

The instructions described above, read verbatim to each S on the first day, were paraphrased each day thereafter. Otherwise, the procedure described was followed for 10 successive, daily sessions for each S. Consequently, each S rendered a total of 100 control matches and 500 experimental.

Transformation of Data

The controls on the apparatus were calibrated in arbitrary units; hence, it was necessary to convert the raw score dial settings to luminance values according to a calibration curve supplied by the manufacturer. It should be noted, however, that no luminance values were provided for dial settings below a luminance value of .05 ft.-L.. Inasmuch as a majority of the scores obtained in the current investigation were, in fact, below this value, it was necessary to

convert the dial settings to luminance values by a process of extrapolation.

RESULTS

The general outcome of the present experiment is epitomized in Fig. 1, which shows the combined Ss' mean scores plotted as a function of practice days. As can be seen from the figure, the scores obtained under the experimental condition are markedly lower than those under the control condition; and both sets of scores tend to decline, especially during the initial days of the experiment.

Table 1 summarizes the analysis of variance performed on the mean daily experimental judgments of all Ss. It will be seen that there is a highly significant subject effect. There is a difference among practice days which could be expected by chance alone less than 6 times in a 100, the p-value calculated by interpolation in the tables given by Owen (1962) being, actually, .054.

Table 2 summarizes the analysis of variance performed on the mean daily control judgments of all Ss. As indicated in the table, there is a highly significant difference among scores for both subject and practice effects.

Fig. 2 is presented finally for the purpose of relating

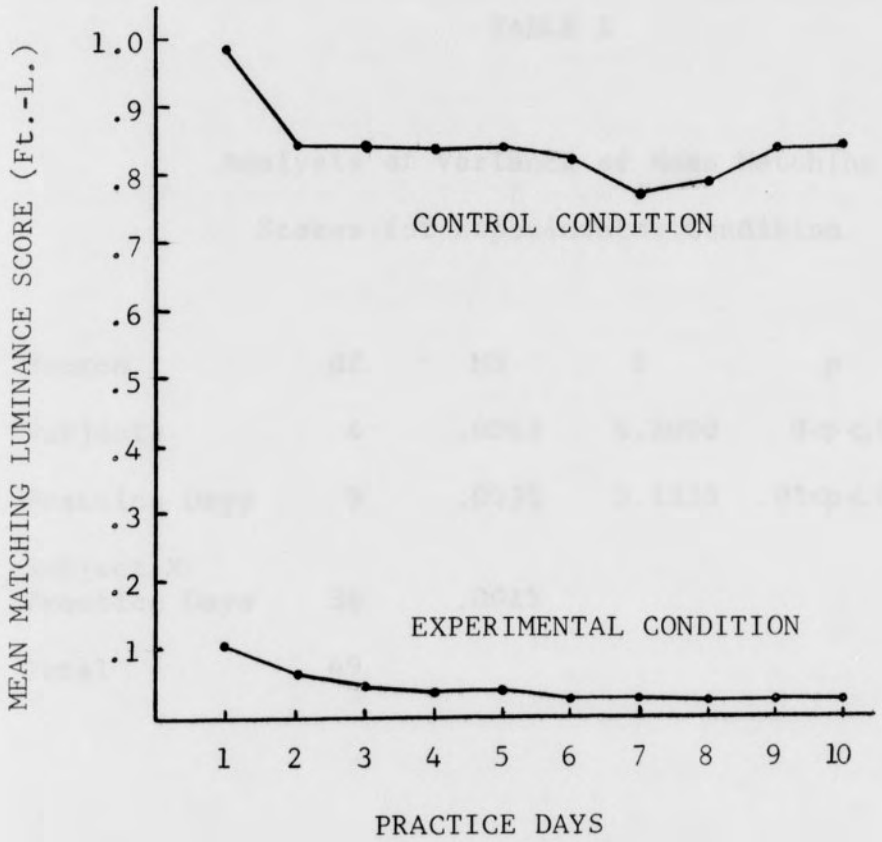

Fig. 1. Mean matching luminance scores as a function of practice days.

TABLE 1

Analysis of Variance of Mean Matching Scores for Experimental Condition

Source	df	MS	F	p
Subjects	4	.0063	4.2000	$0<p<.01$
Practice Days	9	.0032	2.1333	$.05<p<.06$
Subject X Practice Days	36	.0015		
Total	49			

TABLE 2

Analysis of Variance of Mean Matching Scores for Control Condition

Source	df	MS	F	p
Subjects	4	.0252	5.1428	$0<p<.01$
Practice Days	9	.0175	3.5714	$0<p<.01$
Subjects X Practice Days	36	.0049		
Total	49			

the obtained data to what might be considered an especially meaningful psychological scale. Here, the experimental results are plotted upon a logarithmic scale, indicative of the traditionally accepted subjective magnitude of stimuli. As will be seen from Fig. 2, the change in experimental judgments was great, and the change in control judgments was comparatively slight, in such "phenomenological" terms.

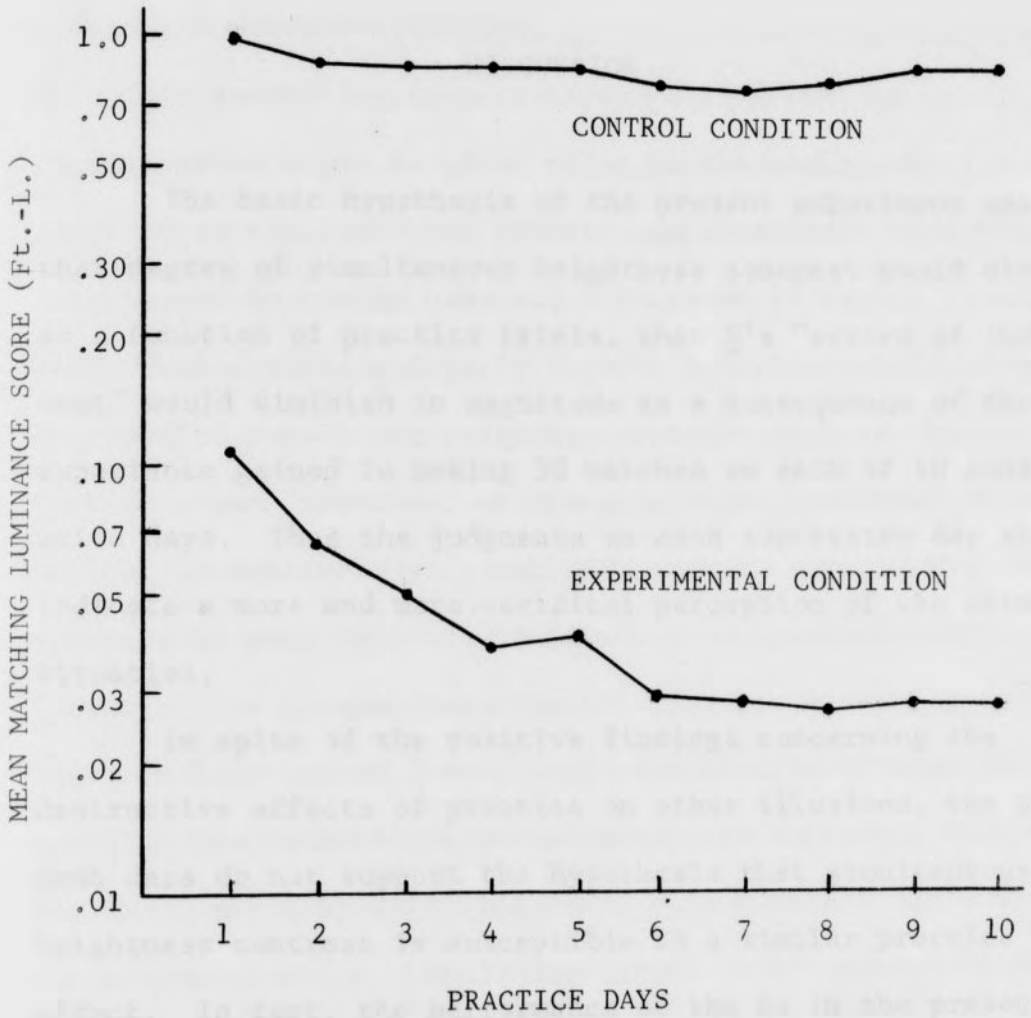

Fig. 2. Mean matching luminance scores, plotted logarithmically, as a function of practice days.

DISCUSSION

The basic hypothesis of the present experiment was that degree of simultaneous brightness contrast would diminish as a function of practice trials, that S's "errors of judgment" would diminish in magnitude as a consequence of the experience gained in making 50 matches on each of 10 consecutive days. Thus the judgments on each successive day should indicate a more and more veridical perception of the stimulus situation.

In spite of the positive findings concerning the destructive effects of practice on other illusions, the present data do not support the hypothesis that simultaneous brightness contrast is susceptible to a similar practice effect. In fact, the performance of the Ss in the present experiment seems to deteriorate, rather than improve. Although it is true that the variability among treatment days is one of only borderline significance, this unexpected and contrary finding is in need of explanation.

Also interesting is the fact that there is a significant difference across practice days for the control condition.

This result, like the principal one, was totally unexpected and will require explication.

In attempting to account for such anomalous results, consideration might be given first to the experimental judgments in particular. Two points seem pertinent: Firstly, experiments involving practice effects on illusions (Judd, 1902; Dewar, 1967) generally involve a rather extensive series of practice trials per session, certainly no less than 50. Such sessions, moreover, should come at a fixed hour on each of the consecutive days comprising such an experiment. Such a procedure was, in fact, followed in the present study. Secondly, the present experimental task was extremely demanding. It required of S very difficult discriminations, each of which was somewhat time-consuming. As a result, even as few as 50 matching trials required approximately one hour of intensive attention. While such problems are common to studies in psychophysics, they seem somewhat magnified in the present investigation. Thus, the standard panel luminance values of 4 ft.-L. and 1 ft.-L., for the center disc and outer ring, respectively, produced a striking simultaneous brightness contrast illusion. Although attention to this stimulus situation is not impossible, it nonetheless requires an extraor-

dinary amount of effort. The particularly demanding nature of the experimental task, in conjunction with the rigorous schedule maintained, suggest that motivational factors could have played a significant role in the outcome of the present experiment. Specifically, such variables as generalized fatigue and/or boredom may well have been important to the experimental results.

It remains to be understood how a variable such as fatigue might have produced the apparent increase in the contrast effect over treatment days that was observed in the experimental condition. A possible explanation may be suggested here. In view of Parrish's (1966) results relative to the effect of analytical set, it is possible that S began at his best level of performance as a result of the highly "analytical" nature of the instructions also used in this experiment. As fatigue or failing motivation became more and more important, it gradually proceeded to mask any analytical attitude which S may have had at the beginning of the experiment. To the extent that motivational factors are correlated with individual differences, the highly significant among-subjects variability reported in Table 1 may be suggestive. It is especially interesting that the performance of one S did

indeed remain essentially stable across trials. If this stability reflects a persistently high level of motivation, it would seem to follow that a decline in the motivational level of the remaining Ss could account for a corresponding decline in attention to the experimental task; consequently these Ss were overwhelmed by the illusion and their performance deteriorated.

It is worth noting incidentally that such logic is not completely without precedent. Woodworth and Schlosberg (1954, p. 23) suggest that, with respect to the Mueller-Lyer illusion, S gradually assumes a more analytical approach and thereby improves in his perceptual judgments during practice. It would follow, therefore, that if S is instructed in an analytical approach to begin with, then the gradual acquisition of an analytical attitude by S through self-discovery is, in fact, unnecessary. Moreover, it is conceivable that such an attitude would suffer with failing motivation.

While the above explanation perhaps has relevance for the results for the experimental condition, it can not explain the apparent decline in control judgments. Although there were only 10 control judgments per session, the apparent ease and speed with which S rendered his judgments seemed to indi-

cate that the task, in the absence of the illusion, was one which S could perform without difficulty. Thus the decline is a very puzzling result. Random variability seems to be an unlikely explanation, in view of the fact that all mean scores were below the value of the standard disc. An empiricistic explanation could only suggest that perhaps their practice in the experimental condition gradually "persuaded" Ss that the standard disc was very dark. Consequently, S rather consistently judged the standard disc to be somewhat darker than it really was. It will be recalled in this connection that, psychologically, the decline in the control scores was trivial, as compared to the decline in scores for the experimental condition (Fig. 2). Alternatively, there is always the possibility that, in spite of instructions to the contrary, the Ss' dial settings for the control condition were a compromise between the settings reflecting an objective brightness match and the nominal amount of adjustment to which they may have become accustomed during the experimental condition.

It should be noted that simultaneous brightness contrast is known to vary as a function of several parameters (e.g., Diamond, 1953; Leibowitz, Mote, and Thurlow, 1953; Torii and

Uemura, 1965; Heinemann, 1955). Other parametric values could have been employed in the present study, and, possibly, different results obtained. A decision was required, however, and that decision was to work with a very compelling contrast effect. In this context, practice, and practice alone, was the single variable systematically manipulated.

In further regard to methodological considerations, one might ask whether or not the psychophysical method of adjustment is appropriate to investigations involving simultaneous brightness contrast. Inasmuch as it has been shown (Diamond et al., 1955) that the method of constant stimuli, the method of limits, and the method of adjustment are equally applicable in the investigation of simultaneous brightness contrast, the employment of the latter technique seems to have been defensible. Additional comments are in order, however, insofar as this particular method relates to the apparatus used in the present investigation. A luminance value of 1 ft.-L. was arbitrarily selected for the center disc on the standard panel. This disc, of course, appeared even less bright than usual upon the presentation of the brighter outer ring or annulus. As a result, the majority of S's settings on the control unit were at the ex-

treme lower end of the scale. Although every attempt was made to control for kinesthetic feed-back resulting from the manipulation of the knob itself (e.g., set screw on control knob), it is possible that, as time progressed, S began using the lower points of minimal luminance as reference points in rendering his judgments of equality. Although this contingency is not believed likely, it cannot definitely be ruled out.

It should be emphasized that the apparent decline in performance over practice trials presents as much of a problem for a nativistic interpretation as it does for an empiricistic. The fact that simultaneous contrast was not stable across practice trials makes a totally nativistic interpretation questionable. Why should there be a systematic change in the physiology of the retina, from day to day? Or, Koehler and Fishback to the contrary, notwithstanding, in the physiology of the cortex? It would appear that, at the very least, the results of the present experiment, in conjunction with other data cited above, make it clear that simultaneous brightness contrast is an effect subject to many subtle influences.

SUMMARY

The present investigation was addressed to the question of whether or not the illusion of simultaneous brightness contrast is susceptible to a practice effect as are the Poggendorff, Zoellner, and Mueller-Lyer illusions. A nativistic, or peripheral, explanation of brightness contrast would predict no change in the degree of the illusion as a consequence of practice. An empiricistic, or central, explanation would predict a decrement in the degree of the contrast effect following successive practice trials.

Five Ss, 3 male and 2 female students of advanced status in the University, participated. Using the method of adjustment, each S attempted to equate the brightness of an adjustable field with that of a standard field of 1 ft.-L. luminance. On each of 10 consecutive days, S rendered: (1) 10 control comparisons in the absence of any contrast effect, and (2) 50 experimental judgments, during which the standard field was surrounded by an inducing field of 4 ft.-L. luminance.

Statistical analysis showed, at a borderline level of

significance, a difference among practice days for the experimental condition. The data show an apparent increase in the effect of the illusion, especially during the first few days of the experiment. Unexpectedly, too, a significant difference among practice days was found for the control condition.

Possible explanations for these anomalous results were discussed. Although the independent variable of practice apparently had an effect opposite to that predicted, it was suggested that the instability of performance across practice days renders a totally nativistic explanation of brightness contrast questionable. It was concluded that at the very least the present data indicate that simultaneous brightness contrast is subject to many subtle influences.

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